# Human Experiments on the Values of Information and Force Advantage

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*If you know your enemy and know yourself, you need not fear the result of a hundred battles—Sun Tzu*

## INTRODUCTION

The ability to obtain and exploit information is a vital part of the Joint Chiefs of Staff's vision of future conflict expressed in Joint Vision 2010 [1]. To ensure that armed forces obtain and use information effectively in conflict, a better understanding of the relationship between information, force advantage, and officers' perception of them must be gained.

This paper summarizes the results of controlled human experiments that address how military officers and Department of Defense analysts use information and perceive its value in a simple contest. See [2] for further details. The experiments also estimate how the same decisionmakers perform when given a force advantage. A force advantage is defined as having better forces than the opponent in numbers, firepower, and/or survivability. The results demonstrate that military decisionmakers often do not use information optimally—even in a simple stress-free situation. Equally insightful, the military decisionmakers significantly overestimated the value of information compared to force advantage, suggesting that they too readily embrace the current enthusiasm for information technologies.

## BACKGROUND

### Information and Decisionmaking in General

There has been a great deal of research on how individual decisionmakers perform, most of it in non-defense contexts. In many cases decisionmakers do not perform optimally or even rationally. A few examples will illustrate the phenomena. Decisionmakers are usually overconfident in their estimates of a situation [3]. Decisionmakers tend to not give as much weight to probabilistic evidence as they should;

and, in terms of Bayes' rule, tend to persist in giving too much weight to their initial estimates [4]. Collecting additional information does not always enhance the quality of a decision when subject to an environment of very high uncertainty [5]. In fact, a decisionmaker with complete information about the opponent's possible outcomes often uses the information disadvantageously, minimizing potential losses rather than maximizing gains [6]. Furthermore, too much information can surpass the decisionmaker's capacity to effectively utilize it [7].

**Previous Research Concerning the Military Value of Information**

The literature conclusively shows that decisionmaking is extremely complex and the value of information can be uncertain. This is probably one reason there is a dearth of quantitative controlled studies using military subjects on the value of information in conflict. Furthermore, very few studies vary both force and information advantage. Much of the research on the military value of information is based on rational choice and the intelligent application of operations research. Bracken and Darilek [8] addressed the question of how much information might be required for a force to achieve information superiority over an opponent in a two-person zero-sum game. They conclude that information can give a force a significant advantage over its adversary when the decisions are made optimally. They note that "non-optimal decision rules can lead to significantly inferior results." Other analyses (with no direct human experiments) have shown varying degrees of the value of information in conflicts using Lanchester models, probability models, and even board games (such as go), e.g., [9], [10], [11], and [12].

Some few studies have involved human subjects. A lengthy study of Army command and control performance measurement [13] found that staff decisionmaking performance could not only be measured, but also improved. However, "the measured relationships between command group performance and command group effectiveness...disappeared almost completely when battle outcome data [effectiveness] were substituted for decision quality [performance]." Sherrill and Barr [14] estimated the links between information level and combat success on six subjects in simulated brigade level combat. They found that "relationships...between information level and battle success appear to have potential utility in allowing one to estimate the impact of proposed

changes in intelligence products or reconnaissance sensors, platforms or tactics." Simpson and Fallesen [15] examined the relationship between conceptual capacity and the ability to discern critical information. Their findings from Advanced Warfighter Experiments, Warfighter Exercises, and Combat Training Center rotations indicated that military leaders were *not* improving in their abilities to determine what information was relevant and how to properly package and disseminate that information to the appropriate level.

Looking across these (and other) studies we see that the value of information in military conflicts depends on the context and is highly variable.

## THE SIMPLE CONTEST

Empirical human experimentation is required to gain an understanding of the value of information in conflict, as well as how it should be presented and acted upon. The variability in humans requires that many subjects participate. This section describes a simple contest that was designed by author McGunnigle to investigate how decisionmakers use information and perceive its value.

### Simple Contest Description

In the simple contest there are two sides and ten positions. The objective of the contest is to control the majority of the positions. Each side is given ten units. Each unit has a number assigned to it, indicating the strength of the unit. In the base contest, each side gets units of strengths 1, 2, ..., 10, which they can place in any of the positions. Each position must be defended, i.e., one unit must be placed in each position. In the base case, neither side knows how the others' units are assigned before the contest is determined. After the final assignment of each side's units, the values are revealed and the side whose unit has the higher strength wins the position. If both sides have the same value at a position, a fair coin is tossed to determine the winner. After all ten positions are evaluated, the side with the most positions wins. If each side holds five positions the contest is a tie.

A force advantage is given to a side by adding a number to each of the side's original unit strengths. For example, a force advantage of one would give a player units

with strength 2, 3, ..., 11. This increases the total force count from 55 to 65, an increase of 18 percent. An information advantage is given to a side by revealing one or more of the opponent's position assignments before the game is evaluated. This allows the player with the information advantage to advantageously assign his units to positions based on the information. For example, an information advantage of three would reveal an opponent's assignment to three positions.

Given an information advantage and assuming that the information given is accurate, an optimal assignment of the units with the information advantage can be made, which is to assign a unit to the revealed position with strength exactly one greater than the opponent's unit, except for the case when the position revealed has a ten assigned to it. In this case, the optimal decision is to assign the unit with a strength of one to that position. If no information advantage is given, the assignment of units to positions has no effect on the probability of winning.

## THE SIMULATION AND HUMAN EXPERIMENTS

The simple contest was used to measure how information and force advantage enhance the chance of winning. To get a baseline result the contest was simulated with optimal decision rules, i.e., no human subjects. These experiments are referred to as the "simple contest *simulation*." The human "in-the-loop" experiments are called the "simple contest *experiment*." In both sets of trials the chances of winning are measured for various levels of force and information advantage. Ties and losses are measured as "not winning."

### The Simulation

Six cases with varying levels of information and force advantage were simulated to measure how advantages in force and information influence the chances of winning with optimal decisionmaking. There is a Blue side and a Red side. Case 1 is the base case, with equivalent forces on each side and no information or force advantage. Cases 2 through 4 examine what happens when Blue has increasing amounts of information by revealing, respectively, the Red force's unit strengths at one, two, and three positions. Cases 5 and 6 give Blue force advantages of one and two, respectively. The probability

that the Blue side wins is estimated by *100,000* trials of the simulation for each case. This provides an accurate estimate of the probability that Blue wins (with a standard error less than .0016).

**The Human Experiments**

To address how military decisionmakers use and perceive information in the simple contest, the same six cases were run with the subject (Blue) playing against the computer (Red). The subjects were 30 military decisionmakers, including Naval officers, Marine Corps officers, and Department of the Navy analysts. The subjects had at least a college degree, and the military subjects ranked from Navy lieutenant to Navy captain.

Each subject was read the description of the contest and then given five practice trials. During the practice trials the subjects were allowed to ask questions about how to use the program. The subjects were then given five trials for each of the six cases. The order in which each trial of each case was presented to the subject was randomized, but known to the subject. The subject had an unlimited amount of time to finish each trial. For each trial, the subject was able to reassign his units as desired and then evaluate the trial. After each trial, the subject was able to see the result as a win, tie, or loss.

After the subject completed the thirty trials they were asked two questions:

- **Question one: Does information revealing the opponent's first position give a better chance, the same chance, or a worse chance of winning the simple contest than a force advantage of one which gives your side units with strengths of 2, 3, ..., 11?"**
- **Question two: Does information revealing the opponent's first and second positions give a better chance, the same chance, or a worse chance of winning the simple contest than a force advantage of one which gives your side units with strengths of 2, 3, ..., 11?**

## EXPERIMENTAL RESULTS

The results of the simulation and human experiments are displayed in Table 1. The probabilities of Blue winning, based on 150 trials (30 subjects with five replications per subject) for each of the six cases of the human experiments, are displayed in column

five of Table 1. Column four displays the probabilities generated by the simulation. The results of the simple contest experiment show the extent to which force advantage and information advantage enhance the chance of winning. The subject's answers to Questions one and two on their perceptions of the values of information vis-à-vis force advantage are displayed in Table 2.

**Table 1. The results of the six cases. The winning proportion increases with an information or force advantage. The P-values with a * correspond to one-sided hypothesis tests, while The P-values with a ** correspond to two-sided hypothesis tests.**

| | Info. advantage | Force advantage | Simulation winning proportion | Experiment winning proportion | Test of equal proportions (P-value) |
|---|---|---|---|---|---|
| Case 1 | None | None | .2936 | .3067 | .7281** |
| Case 2 | One | None | .4742 | .3867 | .0139* |
| Case 3 | Two | None | .6808 | .6400 | .1491* |
| Case 4 | Three | None | .8602 | .7767 | .0034* |
| Case 5 | None | One | .6874 | .6800 | .8461** |
| Case 6 | None | Two | .9239 | .9067 | .4692** |

**Table 2. Summary of survey results. For Question one, the subjects that answered a 'better chance' and the 'same chance' (22 out of 30) overvalued the information advantage vis-à-vis force advantage. For Question two, the subjects that answered a 'better chance' (26 out of 30) also overvalued the information.**

| | Better chance | Same chance | Worse chance |
|---|---|---|---|
| Question one | 13 | 9 | 8 |
| Question two | 26 | 3 | 1 |

## ANALYSIS

Interesting insights can be gleaned by comparing how the subjects perform when given various levels of information advantage and force advantage, and measuring their performance against that of the optimal decisions, as determined by the simulation.

The rows of Table 1, from Case 1 to Case 4, show the benefits of increasing the information that the Blue "commander" has on the Red forces. As expected, the probability of winning increases as the subjects are given more information. However, in Cases 2 through 4 the subjects as a whole did *not* use the information optimally—i.e., as well as the simulated Blue commander. In Case 2 and Case 4 the difference is statistically significant. These tests are one-sided hypothesis tests because we are testing whether the subjects' chance of winning is "equal to" versus "less than" the winning probabilities of the simulation.

The benefits of increasing force advantage is seen by comparing Case 1, Case 5, and Case 6. The probability of winning increases dramatically as the subjects are given a greater force advantage. In these cases, the strategies used by the subjects have no effect on the probability of winning. This was not communicated to them. Therefore, the limiting probabilities that Blue wins Case 1, Case 2, and Case 6 should be the same for the subjects and the computer. This is verified by the hypothesis tests. Here, two-sided hypothesis tests are used because we were testing whether the subjects' chance of winning was "equal to" versus "not equal to" the winning probabilities of the simulation.

Across the various levels of force advantage and information advantage a clear ordering is possible. A force advantage of one is preferred to an information advantage of one and is about equal to an information advantage of two. An information advantage of three is preferred to a force advantage of one. But, a force advantage of two is preferred to an information advantage of three. This ordering applies to both the experiments and the simulations. Yet, the subjects overestimated the value of information vis-à-vis force advantage—even after completing five trials with feedback for each of the six cases. The most striking is that 22 of 30 subjects did *not* prefer a force advantage of one to an information advantage of one, even though the force advantage of one out-performed the information advantage of one by .6800 to .3867. Considering the experiment's simplicity, this suggests that military decisionmakers in real situations may sometimes overvalue the benefits of information.

## CONCLUSIONS AND RECOMMENDATIONS

These experiments contribute to understanding how information might affect military conflicts by utilizing a reasonable sample of military subjects in a controlled environment and varying both information and force advantage in thousands of computational experiments. The results suggest that it may be more difficult to realize the benefits of information superiority than many believe. The implication is that enthusiasm for information technologies should be tempered in arriving at the best balance between more knowledge and more forces. Of course, the value of information in conflict will depend strongly on many factors, including: the scenarios, the timeliness and accuracy of the information, and the talent and experience of tactical commanders under stress. Gaining an understanding of the value of information across this breadth of conditions requires extensive controlled human experimentation. Towards that goal we would like to see:

(1) Many more simple and focused controlled human experiments with varying levels of information, its accuracy, and how it is presented to decisionmakers in a variety of conditions and scenarios.

(2) The establishment of a searchable catalogue on the results of studies on the value of information with which analysts could synthesize what the whole of the experiments show. This should include everything from large in-the-field tests, such as the Warfighting Experiments, to rigorously controlled human experiments as in this study, to computer simulations and mathematical analysis. This will facilitate identifying clear trends where information superiority will have a big payoff and what other forms of force advantage are needed to realize it.

*Though an obstinate fight may be made by a small force, in the end it must be captured by the larger force —Sun Tzu*

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